1. Block K^1_t multiplies the commanded torque T^*_{crank} by a well known formula to obtain the motor torque producing current I^*_{qs}.

2. PID block represents a proportional-integral-derivative voltage regulator, having as its input a voltage error (Difference between the commanded voltage, V^*_{reg} and the actual, measured DC voltage, V_{dc}). The most general form the voltage regulator is shown.

3. K_v block scales the output of the voltage PID controller and converts it to the commanded generator torque producing current i^*_{qs}.

4. Switches S1 and S2 are the software switches, which select the operating mode:

S1 switch selects between the motor (upper position) and the generator (lower position) commanded torque producing current i^*_{qs}. The switch S1 also selects the number of machine poles (high number for motoring operation, upper position and lower number for generator operation, lower position).

S2 selects between low speed flux command (upper position) and high speed generator or motor flux (lower position).

5. Flux estimator block calculates the machine actual flux from the commanded machine voltage $V^*_{\alpha\beta}$ and flux position ($\sin\theta$, $\cos\theta$) and the measured machine currents i and the DC voltage V_b.

6. Flux Optimizer block performs two functions:

(a) It adjusts the commanded flux for high speed operation in function of the machine synchronous speed ω_o

(b) It regulates the machine flux level in high speed mode by comparing the adjusted commanded flux with the estimated flux and processing their difference through a PI flux regulator. The output from the regulator defines the commanded flux producing current, I^*_{ds}.

7. Slip calculation block computes the exact commanded slip speed ω^*_{slip} required by vector control:

$$\omega^*_{slip} = \frac{L_m}{T_r} \frac{i^*_{qs}}{i^*_{ds}}$$

where T_r is the rotor time constant, L_r/R_r

8. The slip speed is integrated in this block to obtain the "slip angle" θ_{slip}

9. This block ads the commanded slip angle θ_{slip} to the measured rotor position angle θ_r to obtain the angle θ which represents the position of the rotor flux.

10. The derivative block calculates the machine synchronous speed ω_c by differentiating rotor flux position, θ.

11. The sine and cosine generator calculates these functions of the angle, for every position of the rotor flux.

12. This block transforms the measured currents from stationary (α-β) to synchronously rotating (d-q) reference frame using $\sin\theta$ and $\cos\theta$ functions.

13. This block represents 2-channel current regulator, in the synchronous reference frame. It compares commanded i^*_q and i^*_d currents with the measured i_d and i_q currents and processes their respective differences through a PI regulator. The output of the current regulator represents the commanded voltages V_{dq}.

14. This block transforms the commanded voltages V^*_{dq} from synchronous (d-q) to stationary (α-β) reference frame.

15. This block transforms commanded voltages from 2-phase stationary to 9-phase stationary reference frame.

16. This block transforms measured currents from 9-phase stationary to 2-phase stationary reference frame.

17. This block (K^{-1}) scales the measured DC voltage to signal level, for control purposes.

The blocks that are outside of the microprocessor or the DSP are described as follows:

A. The power inverter, which converts the battery DC into AC power during motoring and the generator AC into DC power during generation. In this particular example, the inverter is shown with nine phases at the output.

B. FPGA (Field Programmable Gate Array) which is used to define the PWM pattern for control of the inverter switches. (The PWM pattern determines the "on" and "off" time for each of the inverter switches)

C. The Induction Machine, which is designed so that it can be controlled with a Pole-Phase Modulation method. In this particular example, the induction machine is shown with nine phases.

D. The position sensor, which measures the instantaneous rotor position θ_r. In this example, the position sensor is shown to be an incremental encoder. --

REMARKS

By this amendment, the specification has been amended and proposed drawing changes are submitted herewith. Currently, claims 1-14 are pending in the application.

Examiner Gonzalez and Supervisory Patent Examiner Ramirez are thanked for the courtesies extended to the undersigned and Mr. Stefanovic during the personal interview on June 10, 2002. During the interview, all of the claims and U.S. Patent Nos. 4,489,265, 5,350,988 and 5,977,679 were discussed. Agreement was reached during the interview that the combination of the Le and